LARGE-SCALE RADIOACTIVE CONTAMINANT TRANSPORT METHODOLOGY VALIDATION

TECHNOLOGY DESCRIPTION

Nuclear fuel cycle activities of the Former Soviet Union have resulted in significant contamination of the environment in western Siberia. Pacific Northwest National Laboratory (PNNL) is developing, jointly with their Russian counterparts in the Ministry of Atomic Energy of the Russian Federation (MINATOM), multi-scale, three-dimensional (3-D) models of the hydrogeology and potential contaminant migration in the West Siberian Basin. These models and this modeling strategy will be validated using decades of data from measured contaminant migration at the Mayak, Seversk (Tomsk-7), and Zhleznogorsk (Krasnoyarsk-26) sites. This project is being conducted under the auspices of the Joint Coordinating Committee for Environmental Remediation and Waste Management (JCCEM).

The long-term goal of this work is to test and build confidence in the capability of the U.S. Department of Energy's (DOE's) contaminant transport models to predict future impacts of radioactive contaminant releases at DOE sites on the environment and humans. Our joint objectives are to develop semi-automated approaches integrating site characterization, conceptual modeling, and numerical modeling for radioactive contaminant transport and to validate them in multi-scale, 3-D, transient contaminant transport models for the Mayak and Seversk regions. This proven technology will then be transferred for use at DOE sites. DOE uses such models to evaluate the potential for risk from contaminated U.S. sites, and will benefit both from model validation and from technologies transferred from Russian site remediation work.

Current efforts in contaminant-transport model development are frequently behind schedule and over budget. The overall system architecture is muddled; i.e., site characterization data management, numerical model development, and evaluation of results are intermingled, and specialist roles are not well defined or managed. Site models are slow to mature, difficult to revise as new information or insights are gained, and difficult to document. Further, the physical bases of these models have not been tested "in combat;" i.e., at field scale, for substantial radionuclide concentrations, over decades of migration.

The semi-automated approach being developed and implemented in this project will result in significant cost savings and risk reduction. Cost savings will result from separating the development and implementation of the site-characterization/geographic information system (GIS) database, conceptual model development, numerical model development and implementation, and evaluation of results. Further, automation of links between components and development of the numerical representation of the conceptual model will allow a rapid-turnaround evaluation of changes to site characterization data and the site conceptual model. These savings will allow expedited assimilation of new data and hypotheses, reproducible, easily documented implementation of the numerical model, and comparison with results of "full-scale field experiments," all of which reduce the risks associated with site modeling.

TECHNOLOGY NEED

This joint United States-Russian modeling of well-characterized contaminated sites will provide existing DOE contaminant transport models with much-needed automation and validation. The application of such proven models at most DOE facilities, particularly the most contaminated, will provide a sound, internationally peer-reviewed basis for forecasting the migration of radioactive contaminants, developing remediation strategies, and communicating them to regulators. This work is incorporated in the "FY 2000 Groundwater/Vadose Zone Integration Project Need Summaries," which is the basis for the Hanford Site Technology Coordination Group (STCG) Subsurface Contamination needs for FY 2000.

TECHNOLOGY BENEFITS

Our new technology provides a semi-automated approach to integrating site characterization, conceptual modeling, and numerical modeling for radioactive contaminant transport tested against full-scale

problems that have been monitored for decades. Automation of model construction and deployment will advance the state-of-the-art in hydrogeological characterization science and multi-scale, 3-D model development. Cost savings and improved efficiency will result from:

- Separation of the development and implementation of the site-characterization/GIS database, conceptual model development, and numerical model development and implementation.
- Evaluation of the results.
- Automation of the links between components.
- Development of a numerical representation of the conceptual model.
- A rapid-turnaround evaluation of changes to the characterization/conceptual model.

This approach will substantially reduce the risks associated with complex site modeling by expediting the assimilation of new data and hypotheses, and by allowing reproducible, easily documented implementation of the numerical model. Finally, the credibility of DOE's modeling technology will be demonstrated through the validation of contaminant transport models developed by DOE scientists using decades of Russian groundwater sampling data. The results of this project will improve risk assessments and remediation plans, increase stakeholder confidence, and potentially lower site characterization and remediation costs at DOE sites. Technical collaboration with FSU states and scientists on large-scale groundwater contaminant migration provides new insights, new information, and international peer review of DOE technologies.

TECHNOLOGY CAPABILITIES/LIMITATIONS

The primary applications for this technology are to forecast radioactive contaminant migration at DOE facilities, particularly the most contaminated. The new, internationally peer-reviewed technology will help DOE site managers optimize site characterization and remediation activities. The challenge will be to provide the technical and software foundations of our approach in a generally usable form for DOE-wide application.

COLLABORATION/TECHNOLOGY TRANSFER

Collaborators

- PA Mayak - Field and laboratory studies for the Mayak Site.
- PSA Hydrospetzgeologiya, Moscow and Mayak - Field studies and groundwater and transport modeling for the Mayak and Seversk sites.
- Institute of Physics and Power Engineering, Obninsk - Groundwater and transport modeling for the Mayak and Seversk sites.
- VNIPIPromtechnologii, Moscow - Field studies and groundwater and transport modeling for the Seversk Site.

Technology Transfer

No patents are expected for this technology. Technology transfer to other DOE sites will be by documentation, publication, and training. Since the same modelers work on both projects, the technology is implemented at Hanford as soon as it is developed.

Publications

- Foley, M.G., D.J. Bradley, C.R. Cole, J.P. Hanson, K.A. Hoover, W.A. Perkins, and M.D. Williams. *Hydrogeology of the West Siberian Basin and Tomsk Region.* PNL-10585. Pacific Northwest National Laboratory, Richland, Washington (1995).

- Foley, M.G., D.J. Bradley, C.R. Cole, K.A. Hoover, M.D. Williams, J.L. Devary, J.P. Hanson, L.G. McWethy, W.A. Perkins, and S.K. Wurstner. "West Siberian Basin Hydrogeology-Regional Framework for Contaminant Migration from Injected Wastes," *Deep Injection Disposal of Hazardous and Industrial Wastes.* Eds., J.A. Apps and C-F Tsang. Academic Press (1996).

- Foley, M.G., C.R. Cole, C.D. Gullett, M.D. Williams, L.J. Alexander, and J.C. Bennett. "PNL FY 1995 Local-Modeling Activities for the Tomsk Site, West Siberian Basin," Pacific Northwest National Laboratory, Richland, Washington (September 1995).

- Hoover, K.A., M.G. Foley, E.A. Allen, and J.B. Topping. "PNL FY 1995 Local-Modeling Activities for the Mayak Site, West Siberian Basin," Pacific Northwest National Laboratory, Richland, Washington (September 1995).

- Williams, M. D., C. R. Cole, M. G. Foley, and S. K. Wurstner. "GeoFEST: An Integrated GIS and Visualization Environment for the Development of Three-dimensional Hydrogeologic Models," in *Application of Geographic Information Systems in Hydrology and Water Resources Management.* IAHS Pub. No. 235, Institute of Hydrology, Wallingford, Oxfordshire, UK. (1996).

- Hoover, K.A,. M.G. Foley, E.A. Allen, L.J. Alexander, and M.I. McKinley. *West Siberian Basin Hydrogeology: Site Characterization of Mayak, Tomsk-7 and Krasnoyarsk-26.* PNNL-11457, Pacific Northwest National Laboratory, Richland, Washington (1997).

- Williams, M.D., C.R. Cole, M.G. Foley, K.A. Hoover, and L.J. Alexander. "Development of A Three-Dimensional Regional Hydrogeologic Model of the Mayak Site, Urals," Pacific Northwest National Laboratory, Richland, Washington (September 1997).

- Hoover, K.A., M.G. Foley, C.R. Cole and M.D. Williams. "PNNL FY 1998 Regional Finite-Element Model for the Mayak Site, West Siberian Basin," Pacific Northwest National Laboratory, Richland, Washington (September 1998).

- Rybal'chenko, A. I., M. K. Pimenov, P. P. Kostin, and others. *Deep Injection Disposal of Liquid Radioactive Waste in Russia*. M. G. Foley and L. M. G. Ballou, Eds. Battelle Press, Columbus, Ohio, 206 p. (1998).

- Hoover, K.A., M.G. Foley, C.R. Cole and M.D. Williams. "PNNL FY 1999 Regional Finite-Element Model For The Mayak Site, West Siberian Basin (September 1999)."

- Cole, C.R., K.A. Hoover, M.G. Foley, M.D. Williams, E. Drozhko, L. Samsonova, N. Vasil'kova, A. Zinin, G. Zinina, and K. Ter-Saakian. In press. "Development and Calibration of a Three-Dimensional Regional Hydrogeologic Model for the Mayak Site, Urals." PNNL-SA-32508. *Hydrological Science and Technology Short Papers*, American Institute of Hydrology.

ACCOMPLISHMENTS

- Completed the regional hydrogeologic model for the West Siberian Basin and published a definitive synopsis in May 1995. This is one of the largest geographic areas ever attempted for modeling and is the proof-of-principle for the systematic approach to remote/local site characterization and analysis that is the basis of our technology. Russian peer review of this effort in August 1995 was very positive and led to PNNL developing the joint United States-Russian geographic information system database for all subsequent modeling of the Mayak, Seversk, and Zheleznogorsk sites.

- Completed the Mayak contaminant-transport model intercomparison study in which PNNL and Russian modelers compared results of their analyses of a two-dimensional problem representative of the Lake Karachay contaminant plume. The results of this study generated manuscripts for two open-literature publications:

--"Modeling Intercomparison Study to Investigate a Dense Contaminant Plume in the Complex Hydrogeologic System Around Lake Karachay, Urals: Part 1. Hydrogeologic Features and Problem Formulation." (To be submitted to *Advances in Water Resources.*)

--"Modeling Intercomparison Study to Investigate a Dense Contaminant Plume in the Complex Hydrogeologic System Around Lake Karachay, Urals: Part 2. Comparison of Model Results." (To be submitted to *Advances in Water Resources.)*

- Published English translation of the Russian book *Deep Injection Disposal of Radioactive Waste in Russia,* Battelle Press, ISBN 1-57477-064-0. (October 1998).

- Completed joint United States-Russian steady-state hydrogeological model of the Mayak region.

Our FY 2000 objective is to complete the joint United States-Russian transient hydrogeological model of the Mayak region in preparation for FY 2001 simulations of the historic Lake Karachay contaminant plume.

TECHNICAL TASK PLAN/TECHNOLOGY MANAGEMENT SYSTEM INFORMATION

TTP No./Title: RL35C223 - Joint Coordinating Committee for Environmental Remediation and Waste Management (JCCEM) Contaminant Transport Studies
TTP No/Title: RL34C221 - International Environmental Assessment (This is the predecessor project conducted from FY 1992 to FY 1996.)
Tech ID/Title: 775 – JCCEM Contaminant Transport Studies - PNNL

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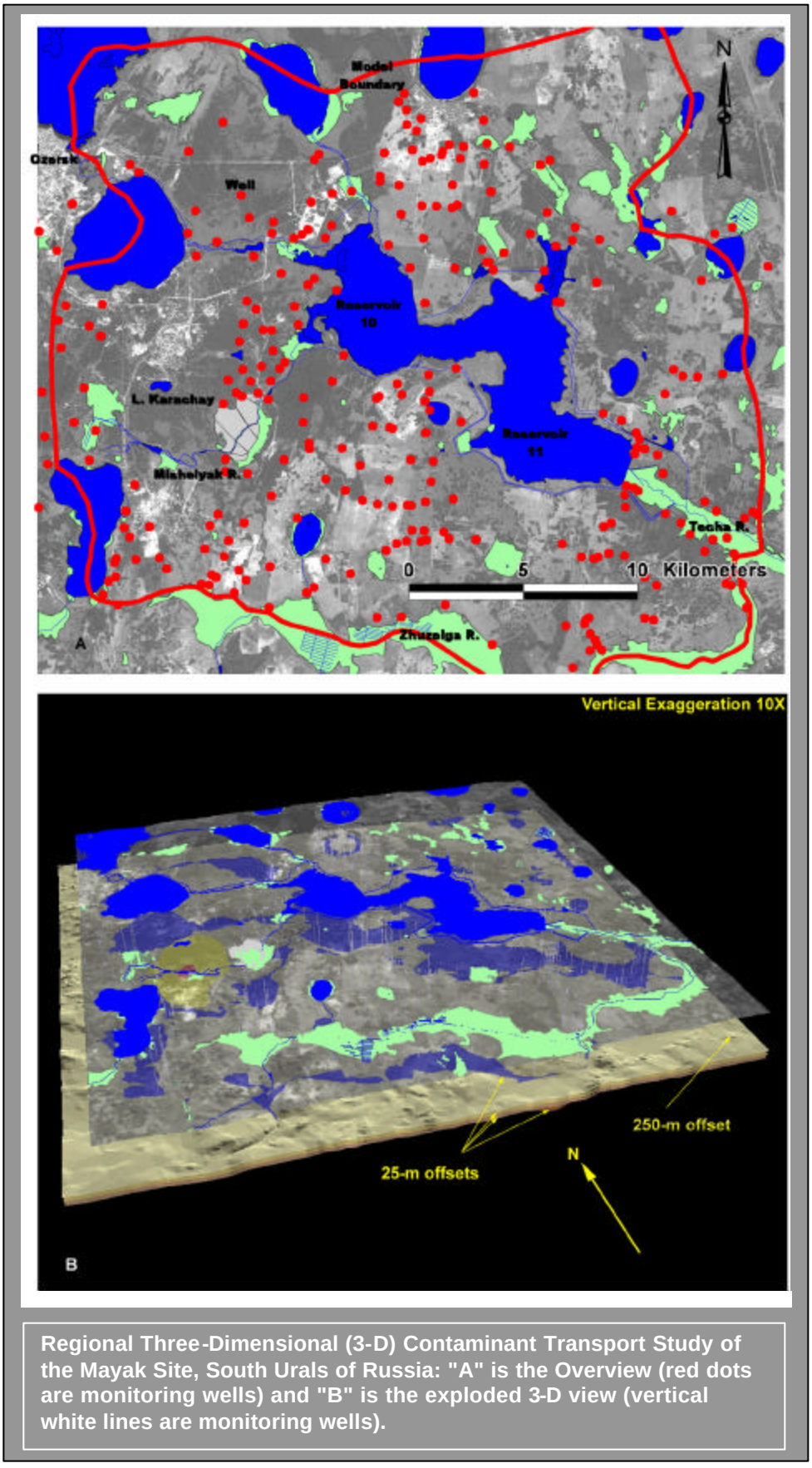
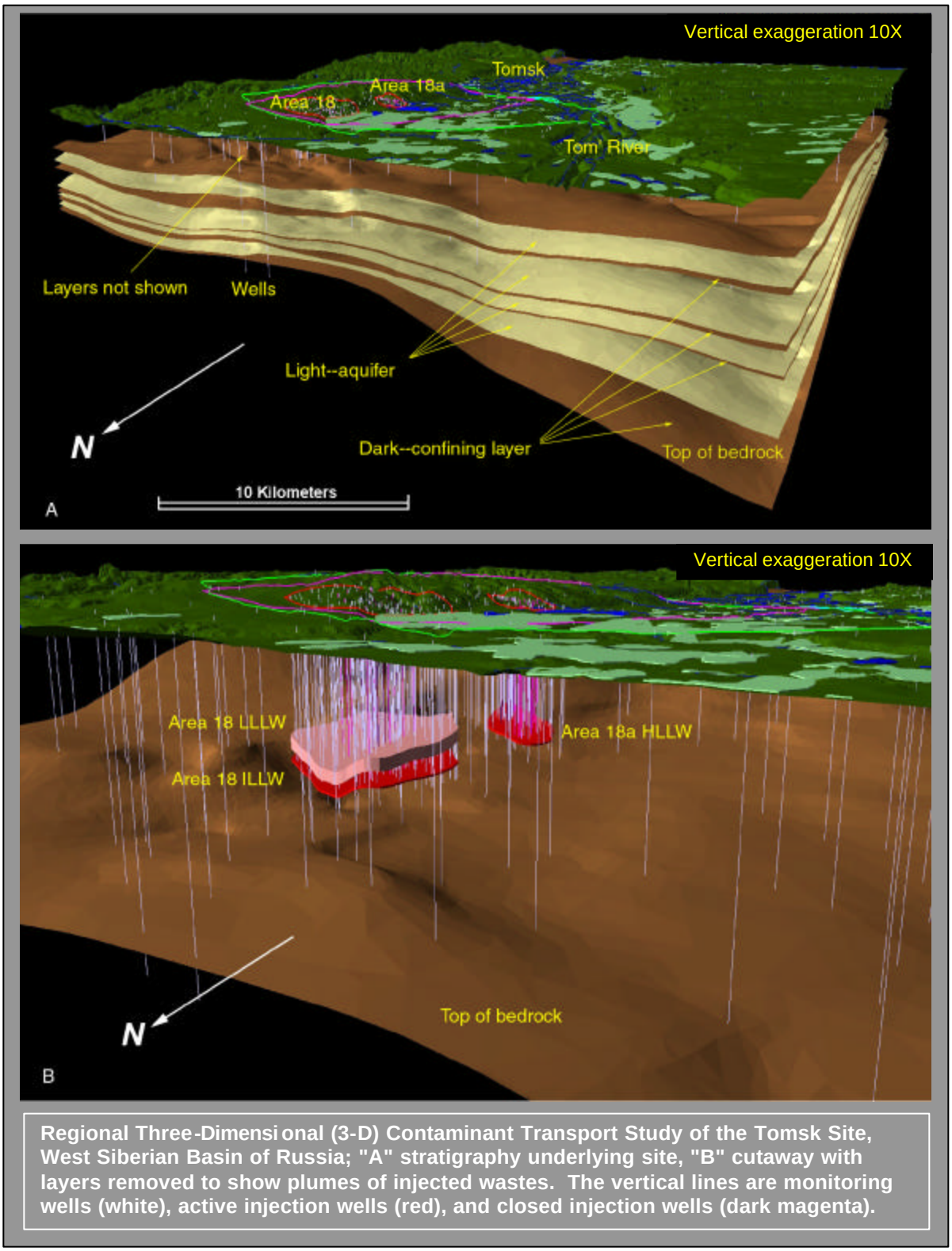


Regional Three-Dimensional (3-D) Contaminant Transport Study of the Mayak Site, South Urals of Russia: "A" is the Overview (red dots are monitoring wells) and "B" is the exploded 3-D view (vertical white lines are monitoring wells).



Regional Three-Dimensional (3-D) Contaminant Transport Study of the Tomsk Site, West Siberian Basin of Russia; "A" stratigraphy underlying site, "B" cutaway with layers removed to show plumes of injected wastes. The vertical lines are monitoring wells (white), active injection wells (red), and closed injection wells (dark magenta).